Sustainable Agriculture

In Action at the Beltsville Agricultural Research Center

INTEGRATED SUSTAINABLE VEGETABLE PRODUCTION SYSTEMS: OVERVIEW AND PLANNING AT THE BELTSVILLE AGRICULTURAL RESEARCH CENTER AGRICULTURAL RESEARCH SERVICE UNITED STATES DEPARTMENT OF AGRICULTURE

Tuesday
February 25, 1997
8:30 a.m.
Auditorium, Building 003, BARC-W
Beltsville, Maryland

INTEGRATED SUSTAINABLE VEGETABLE PRODUCTION SYSTEMS: OVERVIEW AND PLANNING AT THE BELTSVILLE AGRICULTURAL RESEARCH CENTER AGRICULTURAL RESEARCH SERVICE UNITED STATES DEPARTMENT OF AGRICULTURE

Tuesday
February 25, 1997
8:30 a.m.
Auditorium, Building 003, BARC-W
Beltsville, Maryland

TABLE OF CONTENTS

INTEGRATED SUSTAINABLE VEGETABLE PRODUCTION
SYSTEM: OVERVIEW AND PLANNING

TUESDAY, FEBRUARY 25, 1997
AUDITORIUM, BUILDING 003, BARC-W
BELTSVILLE, MARYLAND 20507

8:30 a.m.	Introduction - **DR. JAMES D. ANDERSON**, Sustainable Agriculture Coordinator and Research Leader, Weed Science Laboratory, PSI
8:40	Welcome - **DR. DARWIN MURRELL**, Director, Beltsville Agricultural Research Center
8:45	Sustainable production systems for vegetable production - **DR. AREF ABDUL-BAKI**, Vegetable Laboratory, PSI
	Cooperators
9:15	No-till vegetables. **MR. STEVE GROFF**, Groff Farm, Southern Lancaster County, PA.
9:20	Fresh-market tomato production on Maryland's Eastern shore. **MR. ROB HOFSTETTER**, Former Production Manager, Starkey's Farm, Galena, MD.
9:25	Growing snap beans conventionally and with cover crop mulches in the Coachella Valley. **SAM COBB AND SAM ASLAN**, NRCS, Indico, CA and **JOSE AQUIAR**, Farm Advisor, University of California, Riverside, CA.
9:30	A systems approach to assess the environmental impact of sustainable and conventional vegetable production - **DR. CATHLEEN HAPEMAN**, Environmental Chemistry Laboratory, NRI.
9:45	Chesapeake Bay - Impact of farming practices - **MICHAEL HELLER**, Director, Clagett Farm, Chesapeake Bay Foundation.
10:00	BREAK
10:30	Insect pest management in a sustainable tomato production system--Overview of insect pests of tomatoes in Maryland -**DR. KEVIN THORPE**, Insect

Biocontrol Laboratory, PSI

10:35 Colorado potato beetle biology and control strategies - **DR. PAUL TAYLOR**, Department of Entomology, University of Maryland, College Park

10:50 Planned study of insect control in a hairy vetch mulch tomato production system - **DR. KEVIN THORPE**, Insect Biocontrol Laboratory, PSI

11:00 Disease management in a sustainable tomato production system - **DR. LEE DARLINGTON**, Weed Science Laboratory, PSI

11:30 Equipment for no-tillage sustainable vegetable production - **PROF. RONALD MORSE**, Department of Horticulture, VPI & State University, Blacksburg, VA.

NOON LUNCH

1:00 p.m. Breakout Instructions

1:15 Breakout Sessions

Sustainable Production Systems - **DR. JOHN TEASDALE**, Weed Science Laboratory, PSI

Environmental Management - **DR. ALI SADEGHI**, Environmental Chemistry Laboratory, NRI

IPM - **DR. EDWARD DOUGHERTY**, Insect Biocontrol Laboratory PSI

3:00 BREAK

3:15 Summarize material from Breakout sessions

3:45 Oral reports from Breakout sessions

4:00 Closing comments

MILESTONES IN THE DEVELOPMENT OF THE SUSTAINABLE AGRICULTURE PROGRAM AT BARC

1990 - A PROPOSAL BY THE TASK FORCE ON SUSTAINABLE AGRICULTURE RESEARCH AT BELTSVILLE, NOVEMBER 19, 1990

1991 - FORMATION OF THE OVERSIGHT COMMITTEE TO ESTABLISH A SUSTAINABLE AGRICULTURE DEMONSTRATION SITE, NOVEMBER 1991

1992 - ESTABLISHED THE DEMONSTRATION SITE - SOUTH FARM

- ESTABLISHED THE HORTICULTURE SITE - NORTH FARM

1993 - FORMATION OF THE SUSTAINABLE AGRICULTURE PROJECT COORDINATION COMMITTEE

- SELECTION OF THE 40-ACRE SUSTAINABLE AGRICULTURE RESEARCH SITE

- COLLOQUIUM ON RESEARCH ON SUSTAINABLE AGRICULTURE AT BARC, MARCH 18, 1993

1st one INTEGRATED PEST MANAGEMENT FIELD DAY, JULY 23, 1993

1994 - PROGRESS REPORT - SUSTAINABLE AGRICULTURE RESEARCH, FEBRUARY 16, 1994

- INTEGRATION OF SUCCESSFUL SUSTAINABLE AGRICULTURE PRACTICES INTO PRODUCTION FARMING AT BARC

- ESTABLISHMENT OF 40 ACRES OF NATURAL MEADOWS AT BARC

- ESTABLISHED THE RURAL AND URBAN WASTE DEMONSTRATION SITE

- ESTABLISHED THE INDUSTRIAL WASTE DEMONSTRATION SITE

- SUSTAINABLE AGRICULTURE AND INTEGRATED PEST MANAGEMENT FIELD DAY, JULY 20, 1994

1995 - SUSTAINABLE AGRICULTURE AND INTEGRATED PEST MANAGEMENT FIELD DAY, JULY 18-19, 1995

- ESTABLISHMENT OF THE DAIRY MANURE MANAGEMENT PROGRAM

1996 - PROGRESS REPORT AND FUTURE DIRECTION OF THE SUSTAINABLE AGRICULTURE PROGRAM AT BARC, MARCH 14, 1996

- ESTABLISHMENT OF THE FARMING SYSTEMS PROJECT ON THE 40-ACRE SITE

- SUSTAINABLE AGRICULTURE AND INTEGRATED PEST MANAGEMENT FIELD DAY, JULY 18, 1996

- ESTABLISHMENT OF FATE OF PESTICIDE AND NITROGEN IN HORTICULTURE PRODUCTION

- ESTABLISHMENT OF REDUCTION OF FUNGICIDES IN TOMATOES

- ESTABLISHMENT OF IPM CONTROL OF COLORADO POTATO BEETLE IN TOMATOES

1997 - BARC COMPOSTING FACILITY BECAME OPERATIONAL

INTEGRATED SUSTAINABLE VEGETABLE PRODUCTION SYSTEMS: OVERVIEW AND PLANNING - FEBRUARY 25, 1997

FINANCIAL SUPPORT

When the sustainable agriculture program started in the fall of 1992 with the development of the Field Crop Demonstration Project, BARC had little in the way of modern up-to-date farm equipment to support such a program. Because of this lack, field research projects at BARC had to rely heavily on the cooperation of the University of Maryland, particularly during harvest time.

The Area Office was made aware of these problems and it responded by purchasing some needed field equipment. As this new equipment was obtained the Farm Operations Branch (FOB) also purchased additional equipment to support the program. With the initiation of the Site-Specific Management Project in 1995, other equipment was obtained to allow scientists to monitor yields on a real time basis.

In addition to new field equipment, the Area Office furnished funding for soil characterizations and for temporary help at the various sites. A composting facility was also constructed to compost in-house generated organics and to serve as a facility for research on composting and co-utilization of by-products. In the five years since the field programs were initiated in 1992, the Area Office has contributed over $1 million in high priority research funds to the Sustainable Agriculture Projects (Table 1).

At the March 14, 1996 Winter Meeting of the Beltsville Agriculture Sustainable Agriculture Program, the organizing committee recommended that the Area Office give more support to the scientific effort. The Area Office listened. This past year, two new ARS post doctoral Research Associates were awarded to sustainable agriculture projects and additional support was given to partially fund a post doctoral associate, as well as a visiting scientist. Also, funding for additional student summer help was obtained.

The Sustainable Agriculture Programs are now established and the FOB has the most modern farming equipment available to carry out our field research and to adopt, where applicable, our research findings into the Area's farming operations. Yields from all production fields at BARC can now be monitored and mapped. In the current stage, all projects need additional research scientists, research associates and technical support. Beltsville Area administration will continue to increase the use of High Priority Research funds to support personnel, such as research associates, graduate students and technicians. Such support can make participating scientists more competitive in obtaining outside research support in the area of sustainable agriculture.

The research commitment of BARC to Sustainable Agriculture is summarized in Table 2. This shows that about $2.9 million dollars are committed to these projects in FY 1997. The funds are earmarked for five major projects involving 8 different laboratories, at least 30 scientists and 40 support personnel. This funding in sustainable agriculture does not represent new funding, but reallocation of research dollars to this high priority research area.

Table 1. Summary of Funding Support from the Area Office for the Sustainable Agriculture Programs

1992

Equipment:

▪	Combine	$ 67,000
▪	Yield monitor	$ 25,000
▪	Weigh Wagon	$ 7,000
▪	**TOTAL**	**$ 99,000**

FOB labor - 50 hours

1993

Equipment

▪	Global Positioning System	$ 58,000
▪	Haybuster	$ 30,500
▪	Irrigation equipment	$ 9,700
▪	Spectrophotometer	$ 9,000
▪	Cultivator	$ 6,500
▪	Micro-logger	$ 6,200
▪	Super bedder	$ 5,000
▪	Crop Sprayer	$ 3,500
▪	Combine parts	$ 3,100
	SUBTOTAL	$ 131,500
Plant and Soil Analysis		$ 10,500
Extramural support		$ 48,000
Supplies		$ 19,700
	TOTAL	**$ 209,700**

FOB labor - 100 hours

1994

Equipment:

▪	Spading Machine	$ 10,700
▪	Manure Spreader	$ 9,700
▪	Nitrogen Side-dresser	$ 7,700
▪	Computers	$ 6,800
▪	Tiller	$ 4,800
▪	Irrigation materials	$ 4,100
▪	Flail Mower	$ 3,100
▪	Balances	$ 2,700
	SUBTOTAL	$ 49,600

Extramural support	$ 40,000
Soil and Plant Tissue Analysis	$ 4,000
Supplies	$ 20,000
TOTAL	**$113,600**

FOB labor - 180 hours

1995

Equipment

▪	Hammer Mill	$ 3,500
▪	Data Logger	$ 1,300
	SUBTOTAL	$ 4,800

Extramural	$ 4,000
Soil and Plant Tissue Analysis	$ 20,100
Supplies	$ 23,900
Composting Facility	$ 240,000
TOTAL	**$ 292,800**

FOB labor - 180 hours

1996

Equipment

▪	Soil moisture sensors	$ 20,000
▪	High residue shredder	$ 10,100
▪	Cyclone spreader	$ 3,000
▪	Seeder for cover crops	$ 4,000
▪	Run-off monitoring equipment	$ 76,600
▪	Soil moisture monitoring system	$ 24,900
▪	Incubator	$ 6,300

▪ Flail chopper	$ 9,400
▪ Computer	$ 4,400
▪ Pick-up	$ 20,000*
▪ Yield monitor for BARC combine	$ 9,000*
▪ Irrigation system	$ 9,000*
SUBTOTAL	$ 196,700

*Paid for by PSI

Soil and Plant Tissue Analysis	$ 33,000
Temporary Help	$ 39,000
Collaborating Farmers	$ 3,000
Seed and cover crop, etc.	$ 4,000
TOTAL	**$ 275,700**

FOB labor - 180 hours

1997

Equipment	
▪ Micrometerologist system	$ 10,000
• Two-row transplanter	$ 2,000
▪ Irrigation System	$ 6,000
▪ SUBTOTAL	$ 18,000
•	
Temporary help	
▪ Student	$ 29,000
▪ Scientific	$ 27,000
Plants, etc.	$ 4,500
Soil and plant analysis	$ 5,900
Farm collaborators	$ 3,400
Miscellaneous	$ 5,000
Photography	$ 3,400
TOTAL	**$ 78,200**

GRAND TOTAL	**$1,069,000**

Table 2. Distribution of Support for Sustainable Agriculture Activities at BARC - FY97

Project	$'s 1000's	FTE SY's	# SY's	FTE Support	# Support	# Laboratories
Horticulture	763	3.25	11	6.37	17	4
Farming Systems Project	687	2.25	8	3.8	9	3
Field Crop Demo Project	199	0.9	5	2.95	5	2
Composting Site	168	0.8	4	1.9	4	2
Manure Project	855	4.7	12	2.1	11	4
Other	215	0.7	2	0.8	3	2
TOTAL	2,887	12.6	30	17.92	40	8

SUSTAINABLE PRODUCTION SYSTEMS FOR VEGETABLE PRODUCTION

Aref A. Abdul-Baki, Vegetable Laboratory, PSI

Introduction: There are over 60 definitions for sustainable agriculture. In the farmers' language, sustainability means survival on the farm. The need for developing sustainable production systems is to provide the American producer with the technology that keeps him in production amidst rapid economic, environmental and social changes. At the economic level, the U.S. farmer faces keen competition in global agriculture as a result of high production cost arising from labor, equipment, and raw material. At the environmental level, there is an endless list of challenges starting with the conservation of non-renewable resources such as, soil and fuel, and protection of the environment from contamination with fertilizers and pesticides. At the social level, it is essential to improve and preserve the quality of rural life, and provide the consumer with healthy products.

Objective: With the above challenges in mind, we initiated a project at BARC seven years ago, whose goal was to evaluate the major components of the management practices used in conventional systems for vegetable production focusing on (1) their cost/benefit ratio, and (2) their impact on the environment. The long term objective was to identify alternatives to those components and practices in the production systems that would reduce production cost, improve yield and product quality, reduce dependence on non-renewable natural resources, and protect the environment, particularly soil, water, and air.

Approach: Recognizing that no sustainability can last unless the soil is fertile and the production cost is maintained low and competitive, we focused on a plan that would (1) improve soil fertility by increasing the organic matter content and the water holding capacity, and by eliminating soil erosion and loss of nutrients; (2) reduce the use of commercial fertilizers, pesticides, and polyethylene mulches, all of which add significantly to production cost and to environmental pollution. We chose to accomplish this task by incorporating cover crops into the vegetable production rotations based on our knowledge that cover crops have long been known to fix nitrogen (through legume species), recycle nutrients, stop soil erosion, add organic matter, and improve soil water holding capacity. Our research on selecting cover crops adaptable to the mid-Atlantic states culminated in identifying suitable cover crops species for two sustainable production systems: One for spring

vegetables (tomatoes, sweet corn, snap beans, etc.); the other for fall vegetables (broccoli, cauliflower, cabbage, kale, etc.). The use of these cover crops without spring tillage will further reduce soil compaction and improve water infiltration.

Accomplishments:

1. **A sustainable production system for spring vegetables.** This no-spring tillage system uses the winter annual cover crops hairy vetch (*Vicia villosa* Roth) alone or combined with crimson clover (*Trifolium incarnatum* L.) and rye (*Secale cereale* L.). The cover crop(s) are planted in late September and mowed immediately before seeding or transplanting the spring vegetables. The cover crops require no fertilizer, water or herbicides. When mowed they provide an organic mulch 2 to 3 inches thick, that suppresses early weed growth. In addition it adds about 150 lb of N and 2 to 2.5 tons of dry biomass per acre, thereby increasing soil organic matter and water holding capacity, and reducing soil erosion.

2. **A sustainable production system for fall vegetables.** A no-spring tillage system uses summer cover crops to fix nitrogen and produce biomass that gets converted into a mulch by mowing. Forage soybeans (*Glycine max* L.) alone, or combined with millets (*Setaria italica* L.P.), have been effective in suppressing weeds, promoting vegetables' growth, improving soil fertility, and preventing erosion.

Apart from improving soil tilth, yields of fresh-market tomatoes, processing tomatoes, sweet corn, and snap beans increased with the cover crops and production costs were reduced compared to those in the conventional system. **A 3-year economic analysis showed that the increase in yield plus the savings on reducing nitrogen fertilizer and herbicides, and eliminating plastic mulches, resulted in an average marginal profit of $3,900 per acre of fresh-market tomatoes above that attained by the conventional production method.**

Research Activities and Cooperators:

Research activities in the next three years will focus on (a) developing alternative production systems for three major summer crops - potatoes, peppers, and eggplants; (b) establishing supplemental nitrogen fertilizer requirements for sweet corn, snap beans, muskmelons, broccoli, and cauliflower in the alternative production systems; (c) evaluating additional potential cover crops including cow peas and forage soybeans; (d) establishing seeding rates and plant population densities for

vegetables in the alternative systems, (e) evaluating chemical killing methods of cover crops (herbicides) vs mechanical methods (mowing, rolling, etc..) with respect to speed of breakdown, release of nutrients, and suppression of weeds, and (f) determining soil compaction in the conventional and alternative systems and its effect on nodulation of legume cover crops and root development of vegetable crops.

Cooperators include farmers, research scientists, and extension specialists at universities and state departments of agriculture. Some of the current cooperators, their geographical locations, and the areas of cooperation are:

Prof. Ronald Morse, Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA. Cooperates on developing cover crop systems and transplanting methods, evaluating methods, and designing machinery for transplanting and killing cover crops by mowing or rolling.

Prof. Steven Garrison. Rutgers Research and Development Center, Rutgers University, NJ. Cooperates on testing the hairy vetch alternative system for the large scale production of processing tomatoes.

Terry Patton, Department of Entomology, University of Maryland, College Park, MD. Cooperates on implementing the Integrated Pest Management system in our experimental plots.

Sam Aslan, Sam Cobb and Jose Aguiar, USDA/NRCS and Riverside County Extension Service, Riverside, CA. Cooperate on extending the use of the alternative farming systems we developed, in growing vegetables and fruit trees (date and citrus) under high temperature and salinity stresses in the Coachella Valley, Southwest CA.

Michelle Infane, Agriculture Extension Specialist, Rutgers University, N.J. Cooperates on developing an alternative production system for peppers.

Dr. Phil Tipping, State of Maryland Department of Agriculture, Annapolis, MD. Cooperates on insect control by release of predators to reduce or replace use of insecticides for control of major insect pests.

Dr. John Teasdale, Weed Science Laboratory, BARC. Cooperates on developing weed control methods for vegetable production in the alternative systems.

Dr. David Chitwood, Nematology Laboratory, BARC. Cooperates on monitoring changes in populations of pathogenic nematodes in the conventional and the alternative vegetable production systems.

Dr. Gene Galleta, Fruit Laboratory, BARC. Cooperates on extending the use of the alternative production systems to strawberry production.

Norma Wilson, Butterfly Hill Farm, Lovettsville, VA. Cooperates on testing the alternative summer vegetable production systems on her organic farm.

Robert and Pat Bramhall, Bramhall Family Farm, Lothian, MD. Cooperate on testing the alternative production systems for growing fall crops organically on their farm.

Dr. Thomas Devine, Plant Molecular Biology Lab., BARC. Collaborates on developing forage soybean varieties for use as cover crops in the production of fall and early spring vegetables.

Steve Groff, The Cedar Meadow Farm, Holtwood, PA. Cooperates on testing our alternative farming systems on a large scale in the production of summer and fall vegetables, and holds field days annually to neighboring farmers to transfer technology to them.

Prof. Modappa Rangapa, Virginia State University Agricultural Research Station, Petersburg, VA. I cooperate with him on his Capacity Building Grants Program titled "Adoption of Sustainable Crop Production Strategies in Virginia for Herb Products."

Prof. Desmond Mortley, Tuskegee University. I cooperate with him on his Capacity Building Grant Program titled "Using Nitrate Accumulating Under Plastic Mulch Films Through Microbial Transformation for Sweet Potato Production."

Prof. Thelma Miller, Southern University and A&M College, Baton Rouge, LA. I cooperate with her on her Capacity Building Grant Program titled "Production, Storage, and Marketing Strategies for Vegetable Amaranth."

Research Opportunities and Needs: Having established through our research and the research of others, that the alternative production systems improve soil tilth, reduce erosion, increase soil water holding capacity and increase plant growth and yield, the next step is to transfer these findings from individual experiments to integrated farming systems typical of what is actually being practiced on farms. This involves establishing

crop rotations, utilizing on-farm generated waste products of plants and animals (compost, animal manure, etc.), in addition to cover crop residues, as soil amendments, implementing IPM, and evaluating changes in populations of soil microorganisms as affected by soil amendments.

Availability of soil nutrients as affected by cover crops must also be studied. Cover crops recycle large quantities of nutrients, and legume cover crops fix appreciable amounts of nitrogen. Research is needed to establish the effectiveness of cover crops in intercepting nutrients, converting them into biomass, and subsequently releasing them to the vegetable crops. Furthermore, the effect of environmental conditions (rain, soil moisture, soil temperature, microorganisms) on the availability of these nutrients to the vegetable crops must be determined.

The use of living mulches, such as perennial rye grass and tall fescue in traffic areas, as a supplement to the standard cover crops, to provide more effective and longer weed control, needs to be explored. These living mulches are most effective in reducing soil erosion and soil compaction by machinery. However, their competition with the vegetable crops for nutrients and water has not been established.

Publications from research on the project: (limited to the past 5 years).

1. ABDUL-BAKI, A., TEASDALE, J.R., and PRINCE, C. Winter annual legumes as mulches in vegetable production. Proc. of the 23rd Annual Meeting of the Mid-Atlantic Vegetable Workers' Conference, pp. 184-186. 1992.

2. ABDUL-BAKI, A. and TEASDALE, J.R. A no-tillage tomato production system using hairy vetch and subterranean clover mulches. HortScience 28(2):106-108. 1993.

3. ABDUL-BAKI, A., TEASDALE, J.R., CHITWOOD, D.J., and HUETTEL, R.N. Effect of mulches on growth and yield of muskmelons. Proc. of the 24th National Agricultural Plastics Congress, pp. 303-308. 1993.

4. ABDUL-BAKI, A., STOMMEL, J.R., and TEASDALE, J.R. Evaluation of processing tomato varieties in a sustainable agricultural system using hairy vetch mulch. Proc. of the 24th Annual Meeting of the Mid-Atlantic Vegetable Workers' Conference, pp. 1-6. 1994. Accepted January 20, 1994.

5. ABDUL-BAKI, A. and TEASDALE, J.R. Sustainable production of fresh-market tomatoes with organic mulches. U.S. Department of Agriculture, Agricultural Research Service, Farmer's Bulletin FB-2279, pp. 10. 1994.

6. ABDUL-BAKI, A and STOMMEL, J.R.. Pollen viability and fruit set of heat-tolerant and -sensitive tomato genotypes under optimum and high temperature regimes. HortScience 30 (1): 115-117. 1995.

7. ABDUL-BAKI, A. and TEASDALE, J.R. Establishment and yield of sweet corn and snap beans in a hairy vetch mulch. Proc. of Fourth National Symposium on Stand Establishment of Horticultural Crops. Monterey, California, pp. 9-16. 1995.

8. TEASDALE, J.R. and ABDUL-BAKI, A. Soil temperature and tomato growth associated with black polyethylene and hairy vetch. J. Amer. Soc. Hort. Sci. 120:848-853. 1995.

9. KELLY, T.C., LU, Y.C., ABDUL-BAKI, A. and TEASDALE, J.R. Economics of a hairy vetch mulch system in fresh-market tomato production in the Mid-Atlantic region. J. Amer. Soc. Hort. Sci. 120:854-860. 1995.

10. ABDUL-BAKI, A., STOMMEL, J.R., WATADA. A.E., TEASDALE, J.R., and MORSE, R.D. Hairy vetch favorably impacts yield of processing tomatoes. HortScience 31:338-340.

11. ABDUL-BAKI, A., SANAA A. HAROON, and CHITWOOD, D.J. Temperature effects on resistance to Meloidogyne Spp. In tomato exroots with heterozygous and homozygous forms of the Mi-1 gene. J. Amer. Soc. Hort. Sci. 31:147-149. 1996.

12. ABDUL-BAKI, A., TEASDALE, J.R., KORCAK, R., CHITWOOD, D.J., and HUETTEL, R.N. Fresh-market tomato production in a low-input alternative system using cover crop mulch. J. Amer. Soc. Hort. Sci. 31:65-69. 1996.

13. ABDUL-BAKI, A., STOMMEL, J.R., TEASDALE, J.R., and GOTH, R.W. Effect of hairy vetch and black polyethylene mulches on yield and disease reaction of processing tomatoes. Proc. of the 26th Annual Meeting of the mid-Atlantic Vegetable Workers' Conference, p.41-48. 1995.

14. ABDUL-BAKI, A. and TEASDALE, J.R. A review of performance of vegetable crops in plastic and cover crop mulches. 26th National Agr. Plastics Cong. p.1-6. 1996.

15. ABDUL-BAKI, A., HAROON, S.A., and CHITWOOD, D.J. Temperature effects on resistance to Meloidogyne spp. in excised tomato roots. J. Amer. Soc. Hort. Sci. 31:147-149. 1996.

16. ABDUL-BAKI, A., STOMMEL, J.R., WATADA, A.E., TEASDALE, J.R., and MORSE, R.D. Hairy vetch mulch favorably impacts yields of processing tomatoes. HortScience 31:338-340. 1996.

17. ABDUL-BAKI, A., TEASDALE, J.R., KORCAK, R., CHITWOOD, D.J., and HUETTEL, R.N. Fresh market tomato production in a low-input alternative system using cover crop mulch. J. Amer. Soc. Hort. Sci. 31:65-69. 1996.

18. ABDUL-BAKI, A. and TEASDALE,J.R. Growing peppers on polyethylene and hairy vetch mulches. Proc. National Pepper Conf. p. 100-101. 1996.

__Abstracts__

1. ABDUL-BAKI, A., TEASDALE, J.R., Korcak, R., Chitwood, D., and HUETTEL, R. Yield, earliness, and fruit weight of fresh-market tomatoes grown in synthetic and organic mulches. 92nd Annual Meeting of Amer. Soc. Hort. Sci., Montreal. 1995. (Abstract)

2. ABDUL-BAKI, A., HAROON, S., and CHITWOOD, D. Resistance in tomatoes to *Meloidogyne incognita* and *M. arenaria* as affected by Gene Mi and temperature. 92nd Annual Meeting of Amer. Soc. Hort. Sci., Montreal. 1995. (Abstract)

3. ABDUL-BAKI, A. and TEASDALE, J.R. Emergence and field establishment of sweet corn and snap beans in a hairy vetch mulch. 4th National Symposium on Stand Establishment of Horticultural Crops, Monterey, CA. 1995. (Abstract)

4. TEASDALE, J.R., ABDUL-BAKI, A., and POTTS, W.J.E. Growth analysis of tomatoes grown in black polyethylene and hairy vetch mulches. 92nd Annual Meeting of Amer. Soc. Hort. Sci., Montreal. 1995. (Abstract)

5. ABDUL-BAKI, A. Selecting cover crops for vegetable production. 1996. Annual Meeting of the Pennsylvania Assoc. for Sustainable Agriculture. State College, PA. Feb 9-11, 1996.

6. TEASDALE, J.R. and ABDUL-BAKI, A. Weed control for fresh-market tomato production using winter annual cover crops and postemergence herbicides. Annual Report of the 1996 Weed Sci. Soc. Amer. 36:17. 1996.

Citations to the work of A. Abdul-Baki by Technical, Popular Journals and Newspapers

The New Farm. Vetch beats plastic. January 1995. p. 19.

Sustainable Agriculture. A no-tillage tomato production system using hairy vetch and subterranean clover mulches. Winter 1995. p. 13-14.

The 1995 Old Farmer's Almanac. Mulch Magic. p. 206-207. 1995.

The New Bay Times. Editorial-Natural Remedies. March 30, 1995. p.3.

Pennsylvania Farmer. Profits explode in vetch mulch tomatoes. March 1995. p.26-28.

LINK News. Federal Laboratories Consortium honors '95 Tech Transfer Award Winners. 11:1-2. May, 1995.

Current Developments in California............

Agricultural Research. Better than plastic film- Vetch mulch fetches more veggies. p.10-11. May 1995.

The New Bay Times. All Wet for Bay's Sake - one man's war on the silent thief.4:4. Sept. 5, 1996.

Country Folks Grower. Northeast and Mid-Atlantic Edition success stories. p.2 April 1996.

Technology Transfer

Every year, Dr. Abdul-Baki receives several invitations to address scientists, extension specialists, students, commercial growers, and home gardeners. Just to name a few, last year he lectured at the University of California, Riverside, at the Annual Meeting of the Coachella Valley farmers, southwest California; at Delaware State University at Dover, Delaware; at the National Peppers Meeting, Naples, Florida; at the American Society for Horticultural Science Meeting, Lexington, Kentucky; at the Pennsylvania Association for Sustainable Agriculture Annual Meeting, State College, PA; at the Maryland Technology Transfer Conference, Mt. Airy, MD; and at the Rodale Institute Research Center, PA. He participated in five field days, three agricultural fairs, and appeared on two national radio and two TV programs. His Farmers' Bulletin on sustainable production of tomatoes in cover crop mulches was communicated to over 8000 farmers and extension specialists in response to individual requests. He presented information to over 600 visitors who visited his Research and Demonstration Plots at BARC last summer and fall. For his accomplishments in sustainable agriculture he was awarded the 1994 "Friend of the Small Farmer Award", The 1995 ARS Technology Transfer Award, and the 1995 "Federal Laboratories Consortium Award".

Contact: Aref A. Abdul-Baki, Plant Physiologist
Vegetable Laboratory, PSI, ARS, USDA.
Bldg. 010A, Room 213
Beltsville Agr. Res. Service, BARC-West
Beltsville, MD 20705-2350
Phone (301) 504-5057
Fax: (301) 504-5555
E-Mail: vconley@asrr.arsusda.gov

NO-TILL VEGETABLES

Steve Groff, Groff Farm, Southern Lancaster County, PA

My father and I farm 175 acres of corn, alfalfa, tomatoes, pumpkins, soybeans, small grains and a few other vegetables on hilly land in southern Lancaster County, PA. Cover crops and crop rotations are the foundation of our farming system which includes a special emphasis on no-till and mulches. I am the third generation to manage the rolling acres, which have been contoured for at least 40 years. A passionate advocate for soil conservation, soil health and food quality, I started using no-till in the early '80's and cover crops in 1991 as soil conservation measures. I used rye for winter erosion control of fields that would have been bare. Now I plant cover crops based on the succeeding crop that I want to plant into the next year. I am still "finetuning" cover crop mixtures. My preferred cover crops to produce a mulch for growing tomatoes is a mixture of hairy vetch, crimson clover and rye developed by Dr. Aref Abdul-Baki, Plant Physiologist, USDA; and for pumpkins, it's vetch and spring oats. I also plant some vetch the fall before corn whenever possible. Weather or harvest delays or lack of enough openings in the rotation sometimes prevents that, however.

The combination of cover crops and no-till does more than cut erosion--it improves soil tilth, increases organic matter, enhances water infiltration, and lessens pest problems. Leguminous covers, such as vetch or forage soybeans, also add nitrogen to the system and with the manure supplements from our steer-fattening operation, and poultry and hog manure generated on local farms, we find no need for additional phosphorus or potassium.

We have been using a transplanter designed for no-till transplanting of vegetables into killed cover crops. The transplanter was designed and developed by Prof. Ronald Morse, VPI. It has a spring-loaded 20-inch, straight-bladed coulter, followed by a subsurface tiller that gently opens a slot to place the transplant in. It virtually leaves no soil exposed after the seedlings are planted, giving a full and uniform mulch cover for mid- to late-season tomatoes.

Controlling perennial weeds can be a challenge in no-till. However, with proper crop rotation and occasional spot spraying, we have been able to manage weeds effectively. We also noticed less severe defoliation by early blight in the no-till plots as compared to tilled plots. Colorado potato beetles were virtually

absent in the no-till plots, but more apparent in cultivated ones.

We estimate our total savings in the no-till cover crop mulch system to be nearly $550 per acre of fresh-market tomatoes compared to the conventional system. Nearly $500 of the cost reduction is from material, labor and time savings when eliminating use of a plastic mulch. In addition to reducing production cost, the increase in yield and fruit quality generate an additional profit of $2,500 per acre, resulting in a total benefit of $3000 per acre over the conventional system. We believe that plastic mulch would still be needed for early-season tomatoes in wet years. You might notice more slugs, but they haven't adversely affected our fresh-market tomatoes unless the foliage is in contact with the soil.

Erosion control is another area where no-till really shines. With the ground covered by plant residues, soil particles held firmly by the cover crop root network, and soil uninterrupted by tillage, the soil does not erode even by heavy rainfall. With an average soil loss in Lancaster County of 9 tons per acre per year on a typical farm, one begins to realize the importance of preserving this non-renewable soil in place and maintaining its fertility. We had success with no-till pumpkins, sweet corn, peppers, and fall broccoli. Pumpkins are a lot cleaner because mulched soil doesn't splash up on them when it rains as it does when grown under clean cultivation.

Nearly all of our vegetable acreage is in no-till. We made a major improvement on our farming system in 1996 by modifying the method of killing cover crops. We wanted to kill covers mechanically and in a way that would compact them near to soil surface to enhance their decomposition without tilling. We used a rolling stalk chopper designed to flatten and chop corn stalks. The results fall on a scale between flail mowing, which is not efficient, and disking, which creates soil erosion. The turning rollers crimp up the cover and push it right down.

We are also experimenting on other components of the no-till system, such as adding a drip line during the transplanting pass to reduce traffic, and transplanting fall cole crops, such as broccoli, into a summer cover crop system consisting of forage soybean, also developed by Dr. Aref Abdul-Baki. We no-till plant forage soybean in late April or May. By mid-July when it grows to 6 feet high, we roll it down and plant broccoli into it. The bean supplies nitrogen and a soil-protecting cover that suppresses weed growth.

Irrigation can be important for consistent vegetable harvests. The drip tapes should neither be blown away by wind nor buried too deep. With the help of Prof. Ron Morse, Virginia Polytechnic Institute and State University, we rigged a workable system for laying drip lines efficiently. However, it needs further tuning before it would be commercially acceptable.

A Field Day Veteran: We have held a number of field days at Cedar Meadow Farm. The first one in 1994 attracted 25 people, while over 100 attended in 1996. In our 1996 field day, we demonstrated the no-till transplanter, compared our normal hairy vetch cover to an earlier new strain of vetch, transplanted no-till broccoli in mulches of German millet and forage soybean, and observed the rolling stalk chopper in action. With the success we had, we want to make the Field Day an annual event and look forward to the 1997 Field Day around mid-July. The demonstrations convinced the participants that no-till transplanting truly has a place in vegetable production. I'm not doing any economic comparisons or analyses anymore. I'm committed to no-till and to use of cover crops, and will continue "finetuning" the covers and the equipment. You can't just magically do this. It's a system that can always be improved. Our last Field Day's title was "New Generation No-Till Cropping Systems". There's nothing conventional about it--we're not talking Midwest no-till corn and beans here.

I plan to extend whatever experience I have gained to nonagricultural audiences, and get the public more involved. One of the approaches for extending this information is through a professional video, presently in preparation, titled "NO-TILL VEGETABLES - A SUSTAINABLE WAY TO INCREASE PROFITS, SAVE SOIL, AND REDUCE PESTICIDES". Some of my friends are clueless about what we're doing in agriculture for soil conservation, pesticide reduction, water quality protection--we have some hard results that you can't argue against. They provide strong evidence to us and to our visitors that the no-till cover crop system works. The will be explained in detail in the video.

Contact: Steve Groff
Cedar Meadow Farm
679 Hilldale Road
Holtwood, PA 17532
Phone: 717-284-5151
Fax: 717-284-5967

FRESH-MARKET TOMATO PRODUCTION ON MARYLAND'S EASTERN SHORE

Robert J. Hofstetter, Former Production Manager,
Starkey's Farm, Galena, MD

In 1994 and 1995, in cooperation with Dr. Aref Abdul-Baki, USDA-ARS, Starkey Farms Co., Inc., Galena, Maryland, initiated an experiment for the objective of evaluating tomato production in hairy vetch as compared to the conventional method in black polyethylene. The experiment consisted of a one-acre control (black plastic) and one-acre of hairy vetch. The vetch was planted the last week of September, on raised beds at a seeding rate of 25 lbs. per acre. The tomatoes were planted with a no-till transplanter designed by Prof. Ronald Morse at VPI. Fresh-market tomato, variety Sunbeam, was used. Tomato seedlings were planted on 5 foot centers and 24 inches in row spacing. The control was planted the same day using a traditional water wheel transplanter set for the same row spacing. Both plots received a starter solution of 10-20-10 at one gallon per acre at planting time. On the control (plastic), Lexone DF herbicide was applied twice and liquid calcium nitrate was run through the irrigation once every two weeks from transplant to fruit set. Insecticides and fungicides were applied as needed. On the hairy vetch, no additional fertilizer was needed, Lexone was applied only once, and insecticides and fungicide were applied when needed.

In both 1994 and 1995 the tomatoes planted in hairy vetch mulch performed much better than those in black plastic mulch. The growing season was about 2-3 weeks longer and the plants exhibited little to no blossom end rot. The fruit was more uniform in size and color, and the percentage of cracked fruit was much less than in the control. Yields were also much higher on the vetch and production costs were quite different. In conclusion, an average saving of over $700 per acre on production cost was achieved using hairy vetch as opposed to conventional black plastic mulch. An additional $2,000 of profit was achieved as a result of higher yield and fruit quality resulting in a total of $2,700/acre over plastic mulch.

Contact: Robert J. Hofstetter
26825 Lambs Meadow Road
Kennedyville, MD 21645
Phone: 410-348-2084

GROWING SNAP BEANS CONVENTIONALLY AND WITH COVER CROP MULCHES IN THE COACHELLA VALLEY

Sam Cobb and Sam Aslan, NRCS,Indico, CA
and
Jose Aquiar, Farm Advisor, University of California, Riverside, CA

Abstract: In collaboration with USDA/NRCS, USDA/ARS and Cooperative Extension Riverside County, a five-acre experiment was conducted in the summer of 1996 at Sakemoto Ranch in the Coachella Valley, Southwest California, to evaluate production of snap beans (*Phaseolus vulgaris*) in cover crop mulches as an alternative method to conventional production in bare soil. The cover crops included forage soybean (*Glycine max* L.), soybean plus German millet (*Setaria italica* P.L. Beauv), and blackeyed pea (*Vigna unguiculata* L.W. ALP.). The cover crops were seeded on 17 June on raised beds 40 inches wide, and irrigated with buried drip tape. On 30 August, they were lightly incorporated into the beds. The snap bean (*Phaseolus vulgaris*) cultivar (Blue Lake) was seeded into the raised beds on 13 September, using a hand planter. All treatments received the same cultural operations until harvest. The crop was harvested by a commercial harvesting crew and yields were recorded. Yields (lb/acre) were 8,250 in the conventional (bare soil) plots, 7,262 in forage soybean plots, 8,745 in soybean plus millet plots, and 9,735 in the blackeyed pea plots. Yield in blackeyed pea mulch was 18% higher than that in the conventional plots, and that in soybean plus millet was 6% higher than in the conventional plots. This represents a significant yield increase over the conventional method. We attribute the positive responses to cover crops in the Valley soils to the fact that the soils are deficient in organic matter and nutrients. We initiated this research on cover crops because of renewed interest among a number of farmers in the Valley in alternative sustainable vegetable production systems.

Plan: We plan to repeat this experiment in 1997 using the same treatments.

Contacts:

Name: Jose L. Aguiar
Organization: Cooperative Extension, University of California, County of Riverside, 46-209 Oasis Street, Room 103, Indio, CA 92201

Names: Sam Aslan & Sam Cobb
Organization: USDA/NRCS, 80975 Indio Blvd., Suite B-11, Indio, CA 92201

Name: Aref A. Abdul-Baki
Organization: USDA/ARS, Beltsville Agricultural Research Center, Beltsville, MD 20705
Telephone: (301) 504-5047; FAX: (301) 504-5555

A SYSTEMS APPROACH TO ASSESS THE ENVIRONMENTAL IMPACT OF SUSTAINABLE AND CONVENTIONAL VEGETABLE PRODUCTION

Cathleen J. Hapeman, Spokesperson
Environmental Chemistry Laboratory
Natural Resources Institute

Problem statement: There is national concern about the environmental problems associated with widespread use of conventional plastic mulch in vegetable production, which is a high input system involving application of commercial fertilizers and pesticides. One aspect of public concern was reflected in recent articles in the Washington Post (July 7, 1996) and Baltimore Sun (February 14, 1997) which attributed shellfish death to runoff of agrochemicals from plasticulture tomato fields on the Eastern Shore.

Recent work at BARC has led to development of sustainable cultural systems for vegetable production based on the use of the biomass from cover crops as mulching material. The use of cover crops in vegetable production should reduce many of the environmental problems that have been associated with the conventional production systems using plastic mulch. However, there is a lack of information on water dynamics, nitrogen management and pesticide fate and transport within these systems.

Objective: The overall objective of this project is to assess the impact of high input plasticulture and the sustainable vetch mulch system for vegetable production on surrounding ecosystems.

Specifically the team will:

1) Quantify the real-time dynamics of water movement (soil infiltration and runoff) which is important in understanding the fate of agricultural chemicals and the potential for their movement to surrounding ecosystems.

2) Determine water quality by measuring nutrients, agrochemicals, and sediments.

3) Quantitate the dependence on synthetic N fertilizers, noting the contributions of biologically fixed N by the legume cover crops; compare the nitrate leaching, nitrogen mineralization and nitrogen budgets for both systems.

4) Examine and determine kinetic and thermodynamic parameters of

pesticide transformation and sorption; determine the availability of the pesticides on the plastic mulch as a function of washoff versus incorporation to biomass and soil.

5) Measure volatilization of pesticides in production fields.

Approach: The proposed research builds upon the existing sustainable agriculture research programs at BARC that have developed cover crop mulch systems for vegetable production. But, there is a lack of information on water dynamics, nitrogen management and pesticide fate and transport within these systems. A fundamental understanding of water infiltration and movement is essential for understanding movement of agrochemicals in these systems.

A new field study was initiated on the South Farm to accommodate the experimental objectives and necessary monitoring equipment. The Vegetable Laboratory will implement the production systems and measure various production parameters. The Environmental Chemistry Laboratory will monitor the environmental parameters and assess the impact of the two production cultures on the surrounding ecosystems.

The project will consist of 12 plots (4 rows each), 4 for the conventional high input system using plastic mulch and 8 for the sustainable two year rotation (tomatoes and corn) production system using vetch mulch. Flumes and wells will be installed in all the plots. Only the tomato plots will be instrumented each year with real-time soil water monitoring systems and automated runoff flumes for continuous monitoring of water infiltration and runoff.

Planned experiments and measurements by ECL:

1) The contribution of biologically fixed N from the legume cover crops toward N requirements of vegetable production will be assessed by comparison of the N mineralization capacity of soil samples collected from cover crop and plastic mulching systems.

2) Movement and fate of nitrogen in soil will be monitored throughout the year by soil sampling as well as collection of water samples from ceramic cup lysimeters and shallow groundwater wells within the field plots.

3) The movement of pesticides by water transport will be assessed by determining concentrations in water samples collected from the lysimeters, monitoring wells and runoff flumes. Measurements on

the sediments carried by surface runoff water will indicate the degree of soil erosion and the losses of sediment-bound pesticide and nutrient.

4) Real-time soil-water dynamics will be monitored with multi-sensor capacitance probes, standard weather station data, and changes in the ground water table.

5) Micro-meteorological techniques will be used to assess volatile loss of pesticides from these systems. Studies will also assess fate of pesticides within the two systems including mechanisms of photo and thermal degradation as well as possible sorption to plastic material and soil.

6) Laboratory studies involving rainfall simulators will be used to obtain detailed information on the various parameters influencing movement of nutrients and pesticides in these production systems. Large chambers (ca. 45 m^2) will be used to quatitate the effects of soil condition and slope. Laboratory data will be compared to field data to develop modeling parameters.

Accomplishments: This project was initiated in mid-summer 1996. A field with desirable characteristics for runoff monitoring was identified and raised beds were formed in early Fall 1996. Vetch was planted on the sustainable plots. Soil samples were taken and texture, mineral, and organic carbon analyses were completed.

Research Activities and Cooperators: Aref Abdul-Baki, Galen Dively, Cathleen Hapeman, Allan Isensee, Gregory McCarty, Laura McConnell, Clifford Rice, Ioan Paltineanu, Ali Sadeghi, James Starr, John Teasdale, Kevin Thorp and C. Benjamin Coffman.

Research Opportunities and Needs: Production size plots (both sustainable and conventional plasticulture) with very little slope and no wind barriers will be needed for volatilization studies. This will require cooperation with area (Mid-Atlantic) grower(s). Some specialized equipment is required to facilitate automation of sampling and analytic processes of water samples. Additional support for student help is also desirable.

Contact: Cathleen J. Hapeman
Environmental Chemistry Laboratory
BARC-W
Beltsville, MD 20705
(301) 504-6511
(301) 504-5043 (fax)
chapeman@asrr.arsusda.gov

INSECT PEST MANAGEMENT IN A SUSTAINABLE TOMATO PRODUCTION SYSTEM

Kevin W. Thorpe, Research Entomologist, Insect Biocontrol Laboratory
Robert F. Whitcomb, Research Entomologist, Vegetable Laboratory
Aref A. Abdul-Baki, Plant Physiologist, Vegetable Laboratory
John R. Teasdale, Plant Physiologist, Weed Science Laboratory
C. Benjamin Coffman, Agronomist, Weed Science Laboratory
Galen P. Dively, Professor, Department of Entomology, University of Maryland, College Park
Paul Taylor, Postdoctoral Research Associate, University of Maryland, College Park

Objective: To evaluate the effects of mulching systems (plastic versus hairy vetch) and insect pest management systems (seedling treatment with imidacloprid versus foliar application of insecticides as needed) on 1) the quantity and cost of pest control inputs, 2) the type and abundance of beneficial and pest insects (and their damage) in the tomato agroecosystem, and 3) tomato yield and quality. Generated information will be used to develop an insect pest management system that is compatible with a sustainable staked fresh-market tomato production system utilizing a hairy vetch mulch.

Approach: Ongoing work in the Sustainable Agriculture Research Program at the Beltsville Agricultural Research Center (BARC) has established the benefits of a hairy vetch cover crop mulch in a staked fresh-market tomato production system, and an alternative production system using hairy vetch has been proposed to growers. Benefits over the conventional system that uses plastic mulch, cultivation, and high levels of nitrogen fertilizer include reduced fertilizer input, soil erosion, and water loss, increased yield, and a greater profit margin than with conventional plastic mulching systems. The effects of plastic and hairy vetch mulching systems on the diversity and abundance of pest and beneficial insects will be determined by weekly sampling. Insect control measures will be directed primarily against the Colorado potato beetle (CPB), the most important insect pest of tomatoes in the mid-Atlantic region. This pest enters tomato fields at the time of transplanting and, if not controlled, can cause serious damage to the seedlings. To prevent damage to seedlings with a minimum use of insecticides, tomato seedlings in half of the plots will be treated with a low volume of the systemic insecticide imidacloprid (Admire™) prior to planting. This treatment will be compared to a conventional insect management program involving foliar applications of insecticides when

beetles are present. The effects of these insect management strategies on pest and beneficial insects and insecticide inputs will be monitored. A 2 x 2 factorial design with four replications will be used to investigate possible interactions between the mulching and insect management systems.

Accomplishments: This is a new project beginning in FY-97. A literature search was conducted which indicated that this research will address important gaps in knowledge of the effects of the hairy vetch mulch cropping system and seedling treatments with imidacloprid on CPB/natural enemy interactions.

Research Activities and Cooperators: Dr. Galen Dively, University of Maryland, College Park, MD, is an active cooperator in this research project. Dr. Dively and colleagues have developed a method of treating tomato seedlings with imidacloprid prior to transplanting. This method, which drastically reduces the volume of insecticide that is introduced to the production system, has been shown to provide effective control of CPB. Reduced pesticide use strategies such as this are important not only to minimize environmental impacts, but also to delay the development of resistance to this chemical by CPB. With partial funding from ARS, a postdoctoral research associate, Paul Taylor, has been recruited and hired by Dr. Dively to work on this project. Since this pest management approach is likely to be important in a variety of production systems, including those with a high level of sustainability, we feel that it is important to include it in this study. By including the different mulching and pest management systems in the same experiment, it will be possible to study interactions that might affect the degree of pest control obtained or the impact of the pest control method on beneficial insect populations.

Research Opportunities and Needs: This study is designed to explore the effects of the treatments (plastic mulch versus hairy vetch mulch and seedling treatment with imidacloprid versus standard pest management with foliar applications of insecticides) on insect diversity, abundance, crop damage, and interactions among pest insects and their natural enemies (predators, parasites, and diseases). Opportunities exist within this experiment for more detailed study of the biology of both the pests and their natural enemies within these mulching and pest management systems. While the biology and ecology of the CPB have been extensively studied in conventional cropping systems, little work has been done in cropping systems incorporating elements of sustainability. This experiment provides a controlled environment in which certain aspects of CPB behavior, movement, and interactions with natural enemies could

be investigated. In agroecosystems, the CPB usually occurs in "hot spots", which makes this pest a promising candidate for the use of precision farming to target the application of insecticides to only those portions of the field requiring them. An integrated crop management program involving precision farming would require new field sampling or remote sensing approaches for identifying infested parts of the field. Future experiments could include other pest control tactics that are compatible with sustainable vegetable production systems such as use of resistant varieties, microbial pesticides, and augmentative releases of predators and parasites.

Publications and Presentations:

This is a new project in FY-97; no publications to date.

Experimental Design and Procedures: The insect pest management study will be conducted on the South Farm on field SG-11. A second field (SG-12) has been reserved to extend the study into a second year. In these fields, tomatoes will be rotated with corn. Twenty 45′ x 45′ plots(Fig. 1) have been established with 20′ alleys between the plots. Each of the 4 treatment combinations (2 mulching treatments and 2 pest management treatments) will be replicated 4 times. Four plots, 2 with hairy vetch and 2 with black plastic, are designated as untreated control plots with respect to insect infestations. These control plots will be monitored, but no treatments will be applied. The total area in tomatoes will be about 40,500 square feet. The field will be irrigated by 2 systems, one each for the black plastic and hairy vetch mulch replicates. Because no solanaceous crops have been recently grown in the vicinity of this field, low CPB pressure during the experiment is expected. Therefore, CPBs will be collected from other locations and released at an approximate density of 2 beetles per plant to ensure uniform CPB pressure among plots. Vertical aluminum barrier strips will be placed around each plot to limit interplant beetle movement. Insects (both pest and beneficial) will be sampled and defoliation will be estimated twice weekly. In addition to CPB, expected pests include aphids, spider mites, flea beetles, whiteflies, and fruit and foliage-feeding Lepidoptera. Natural enemies that will be monitored are expected to include ground beetles, spiders, lady beetles, predaceous Hemiptera (*Podisus, Perillus, Orius, Geocoris, Nabis*), syrphid fly larvae, and a

variety of parasitoids. All plots not receiving the insecticide drench treatment will be treated with foliar insecticides according to University of Maryland IPM recommendations. Pest monitoring and treatment will be done separately for each plot.

Contact: Kevin W. Thorpe
Insect Biocontrol Laboratory
Room 214, Bldg. 011A
BARC-W
Beltsville, MD 20705
(301) 504-5689
(301) 504-5104 (fax)
thorpe@asrr.arsusda.gov

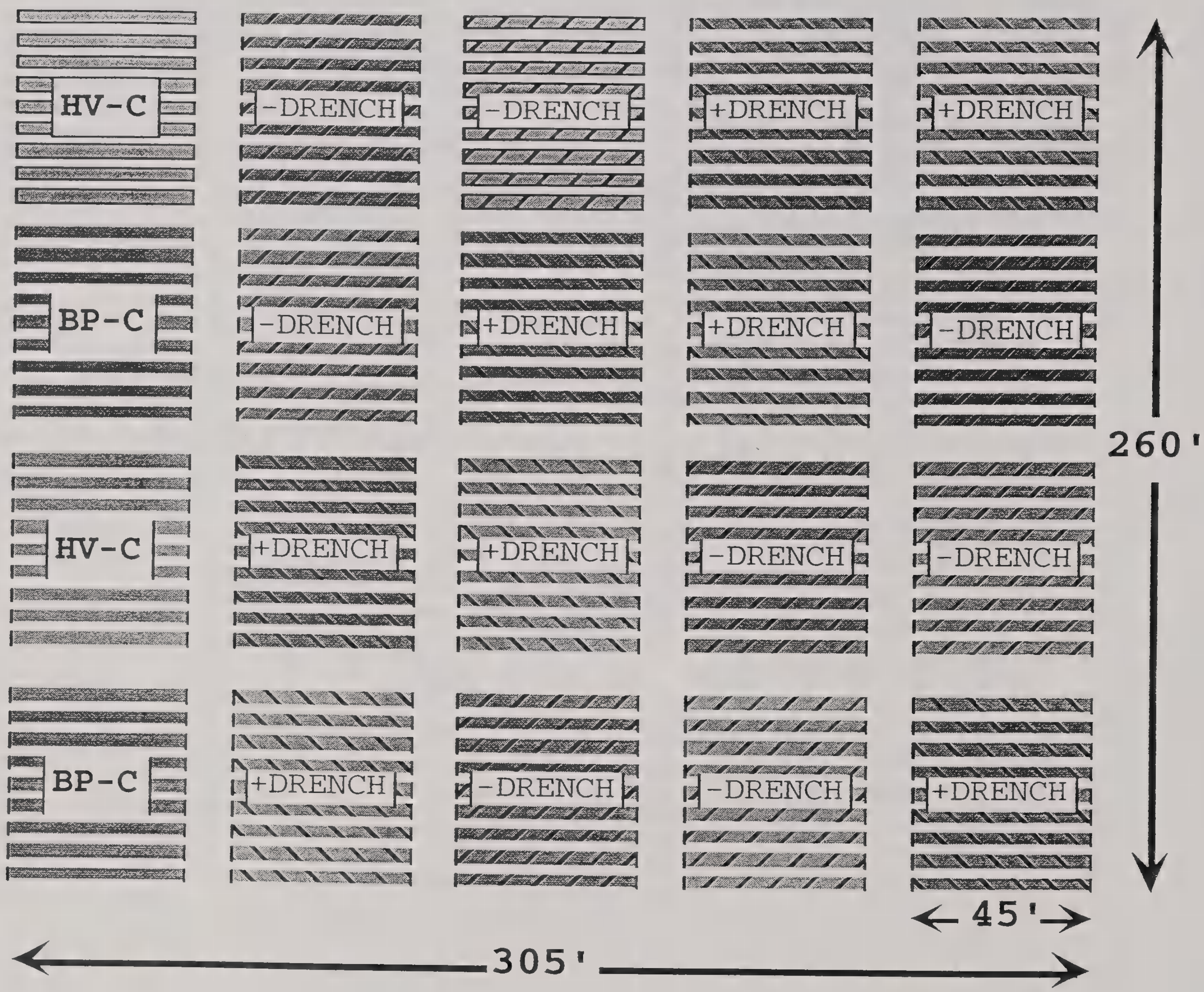

Figure 1. Diagram of field plot.

MANAGEMENT OF DISEASE CONTROL IN A SUSTAINABLE TOMATO PRODUCTION SYSTEM

Lee Darlington[1], Kate Everts[3], John Teasdale[1], Aref Abdul-Baki[2], C. Ben Coffman[1] and James D. Anderson[1]

Weed Science Laboratory[1] and Vegetable Laboratory[2], Plant Sciences Institute, BARC and Department of Horticulure[3], University of Maryland, College Park, MD

Objective: Current production practices of fresh market tomatoes use weekly fungicide sprays to reduce the risk of disease development in tomato production. Fungicides are a potential contaminate of the environment and there are some indications that the efficacy of a widely used one (Bravo) is questioned. Previous research at BARC indicated that tomatoes grown in a hairy vetch mulch live and produce fruit over a longer time span than plants grown in the more conventional method in bare soil or in a black plastic mulch. We assume this is caused by less disease or to an effect on plant senescence. We will compare disease development and its control under 4 cultural practices and 3 different disease control systems.

Approach: In the fall of 1996 a 2-acre field was identified and developed on the South Farm of BARC to initiate the experiment (see figure 1). Raised beds were made and hairy vetch planted so that the experiment could be started in the spring of 1997. The basics of the project will involve growing tomatoes on bare soil, black plastic, hairy vetch and a compost-enriched soil. Tomatoes will be rotated with sweet corn every other year.

Only the tomatoes in the experiment will be treated with fungicide. Weed control will be accomplished according to normal practices or those developed in earlier research at BARC, particularly with hairy vetch (all post emergence and only as needed). IPM insect control will be done according to scouting reports, but will rely on an initial seedling drench with Admire (method developed by Professor Galen Dively) and biological control as much as possible. Eggplant will be planted around the field to act as a trap crop for Colorado potato beetles.

Tomato yield and disease evaluation will be obtained to determine efficacy of treatments. Proposed disease control treatments will consist of: (1) weekly fungicide treatments; (2) no fungicide

treatment; and (3) fungicide treatment as indicated by computer models. However, we will entertain a change if the breakout session comes up with a better alternative. There will be 2 commercial tomato varieties used.

The experiment needs to be carried out for at least 4 years and possibly longer to get results that are meaningful as far as determining the need to spray fungicides.

Accomplishments: This is a new project that is just getting started. We anticipate that this research will lead to new methods of disease control that will be more environmentally friendly.

Research activities and cooperators: Dr. Kate Everts, University of Maryland, College Park, MD, is a collaborator and expert on soil-borne diseases in vegetables and the use of models to predict disease outbreaks. We are in the process of hiring a post doctoral research associate to participate in this project.

Research opportunities and needs: This research project is designed to determine if disease development in tomatoes is affected by cultural practices. Specifically, disease development of staked, fresh market tomatoes grown in bare soil, black plastic mulch, hairy vetch mulch and a farm-produced compost (not selected) will be compared. Also, the control of disease will be compared. We are primarily interested in leaf, stem, and fruit diseases, but soil-borne and postharvest diseases will also be looked at if they become problems. Tomato plants seem to die sooner when grown in bare soil or black plastic than when grown in hairy vetch. Research is needed to determine if this is caused by a disease problem or related more to plant senescence.

We will be able to determine if forecast models such as Tom-cast will be useful in reducing fungicide applications in all cultural practices.

Future research needs to include plant breeding to focus on new germplasm that is resistant to several pathogens and to discover and isolate genes that are important in plant/microbe interactions and the development of the disease process. Also,

fundamental cell biology research is needed to develop new understanding of induced systemic resistance which could lead to novel new approaches of disease control involving the plants own defense mechanisms.

Contact: James D. Anderson
Weed Science Laboratory
Room 342, Bldg. 001
BARC-W
Beltsville,MD 20705
(301) 504-6537
(301) 504-6491 (fax)
janderso@asrr.arsusda.gov

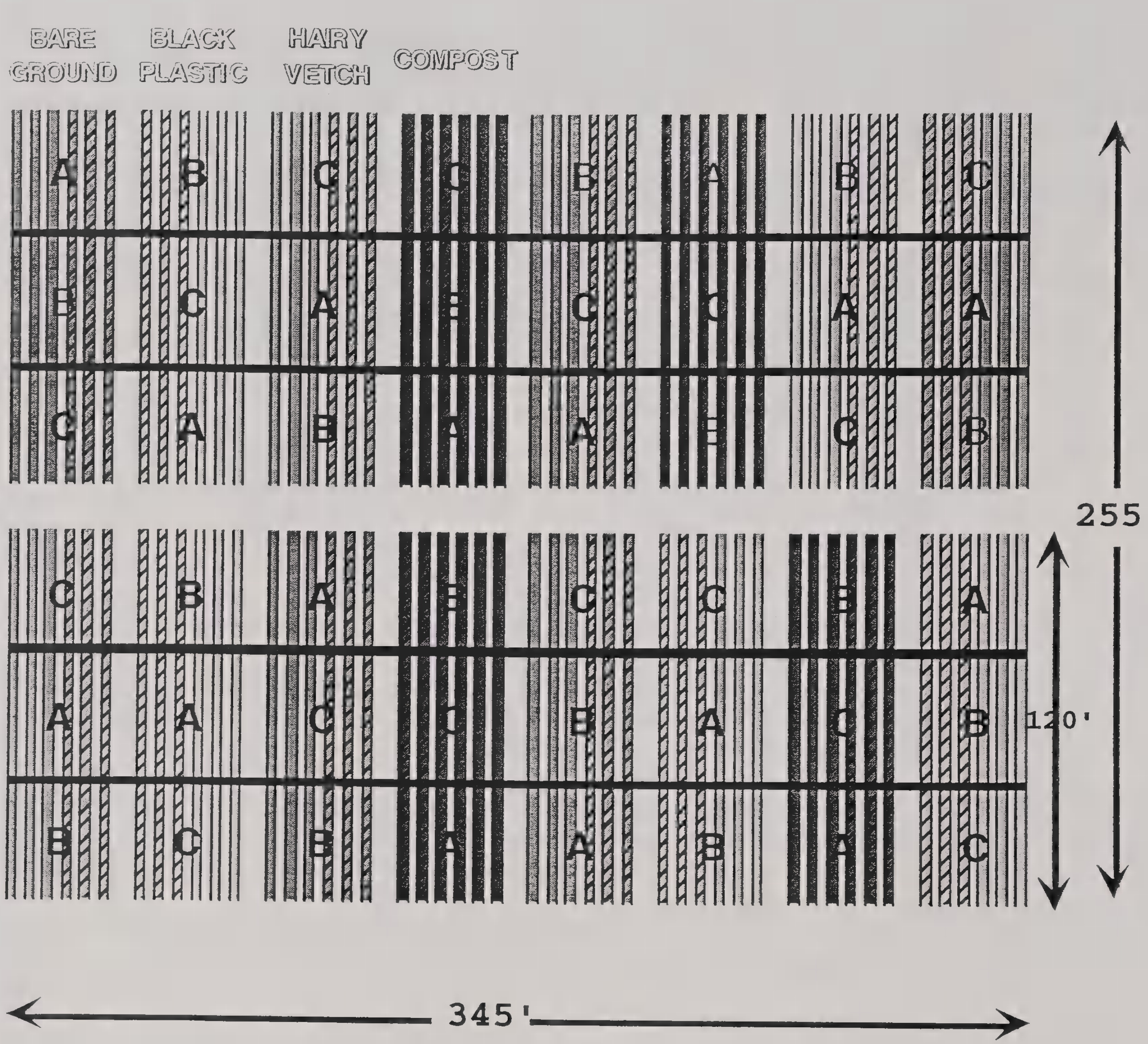

Figure 1. Diagram of field plot.

EQUIPMENT FOR NO-TILLAGE SUSTAINABLE VEGETABLE PRODUCTION

Ronald D. Morse, Department of Horticulture, Virginia Tech, Blacksburg, VA

Abstract: No-tillage can play a primary role in sustainable production systems because of its capacity to conserve soil and water resources. Since high residues often interfere with crop establishment (seeding), seed germination and seeding growth, low-residue no-till systems are normally used for direct seeded crops such as corn, soybean and cotton. However, high residues reduce water (irrigation) and chemical (nitrogen and herbicides) production inputs and are thus highly desirable as we move towards more sustainable agriculture systems. Using vegetable transplants for crop establishment in high residues reduces or minimizes crop interference. Although no-till production systems for transplanted crops are relatively new, the technology needed for success is available. Collaborative no-till research between BARC and Virginia Tech has convincingly shown that high yields can be achieved for several vegetable crops in high residue no-till systems. In recent years, there have been advances in development and utilization of appropriate equipment for production of transplanted crops in high residue no-till systems. A detailed presentation of equipment used in no-till sustainable vegetable production systems will be given. More effort is needed in future years to refine existing equipment and develop new machinery for mechanically killing and planting (for both direct seeded and transplanted crops) into high residue cover crops.

Contact: Ronald D. Morse
Department of Horticulture
Virginia Tech
Blacksburg, VA 24061-0327
(540) 231-6724
(540) 231-3083 (fax)

SUSTAINABLE AGRICULTURE DEMONSTRATION SITE

John R. Teasdale, Principal Investigator
Weed Science Laboratory, Plant Sciences Institute

Objective: To demonstrate the efficacy of sustainable agricultural strategies that are compatible with reduced-tillage systems required on erodible land.

Approach: A 15-acre site on the South Farm of the Beltsville Agricultural Research Center with 2 to 15% slopes has been set aside for demonstrating reduced-tillage sustainable strategies over a long-term (at least 10 years) time frame. Approximately 1/3-acre plots were established in 1993 and four treatments were operational by the 1994 season. All treatments are designed around a two-year corn-wheat-soybean rotation and represent various degrees of reduced tillage, species diversity, and synthetic inputs. There are four replications of each treatment. Treatments include 1) No-tillage (NT) with recommended input of fertilizers and herbicides, 2) Crownvetch living mulch (CV) with crops planted without tillage into a perennial crownvetch cover crop and recommended input of fertilizers and herbicides, 3) Cover crop mulch (CC) with corn planted without tillage into a hairy vetch mulch and soybean planted into a wheat mulch and reduced input of fertilizers and herbicides, and 4) Manure-based system (M) with dairy and green manures incorporated by chisel plowing and no fertilizer or herbicide inputs.

Accomplishments: Yield data from the first three years of operation are presented in Table 1. Corn in the no-tillage (NT) and the hairy vetch cover crop (CC) treatments had the highest yields in 2 of 3 years. Corn in the crownvetch (CV) treatment had the lowest yield in 1995 probably because of competition for soil moisture during a year of low rainfall but had the highest yield in 1996 during a year of high rainfall. Corn in the manure (M) treatment yielded similar to NT and CC in one year but yielded lower in two years. Low corn yield in M in 1996 probably was caused by compaction of tilled soil after heavy rainfall.

Wheat yields were highest in M in 2 of 3 years and probably can be attributed to a tendency for wheat to yield higher in tilled versus untilled soil. Wheat was not harvested in CC but rather used as a mulch for full-season soybeans. This accounts for higher soybean yield in CC in every year compared to the other treatments where soybeans were double-cropped behind wheat.

This data begins to establish the basic performance of these

treatments although trends will only be meaningful with a long-term data set. Soil moisture varies considerably on this site and will be a major factor determining yield. The Environmental Chemistry Lab installed capacitance soil moisture sensors that can provide real-time measurement of soil water dynamics to depths of 1 m. This will contribute to our understanding of water-use efficiency in these cropping systems.

Table 1. Yields at the Beltsville Sustainable Agriculture Demonstration Site during the first three years of operation.

		Yield (bu/A)		
Crop	Treatment	1994	1995	1996
Corn	No-tillage	178 a	106 a	167 b
	Crownvetch	-	58 b	194 a
	Cover Crop	184 a	99 a	156 b
	Manure	147 b	100 a	94 c
Wheat	No-tillage	32 b	55 b	58 a
	Crownvetch	-	-	67 a
	Cover Crop	-	-	-
	Manure	52 a	64 a	42 b
Soybean	No-tillage	47 b	21 b	29 b
	Crownvetch	-	-	31 b
	Cover Crop	61 a	33 a	60 a
	Manure	-	19 b	27 b

Research Activities and Cooperators:

1. Cropping system productivity (biomass, yield, etc.)
   J. R. Teasdale, C. B. Coffman (Weed Science Laboratory)

2. Soil moisture dynamics.
   J. Starr, I. Paltineanu (Environmental Chemistry Lab)

3. Crop physiology with emphasis on water-use and nitrogen-use efficiency.
ARS Research Associate

4. Weed population dynamics.
J. R. Teasdale, C. B. Coffman (Weed Science Laboratory)

5. Economic analysis and systems modeling.
Y. Lu (Systems Research Lab)

6. Spatial/geostatistical analysis.
W. Dulany (Remote Sensing Lab)

7. Nitrate losses and pesticide degradation in selected cover crop-based systems will be studied on nearby sites that are well-characterized and instrumented.
A. Isensee, A. Sadegi, D. Shelton (Environmental Chemistry Laboratory)

Research Opportunities: The 1997 season will be the fourth consecutive year of treatment. Long-term differences in soil and crop responses to treatments are becoming detectable. As a result, these plots should become a valuable resource to scientists exploring various attributes of sustainability.

Important research areas that need investigation:

1. Soil quality changes, long-term. All treatments are designed to improve soil quality but we need some measure of this variable to demonstrate relative changes.

2. Nutrient budget analysis with emphasis on nitrogen input, partitioning, and loss from the system.

Publications from the project in 1996:

KELLY, T.C., LU, Y,C. and TEASDALE, J.R. 1996. Economic environmental tradeoffs among alternative crop rotations. Agric. Ecosyst. Environ. 60:17-28.

TEASDALE, J.R. and COFFMAN, C.B. 1996. The Beltsville sustainable agriculture demonstration for reduced-tillage cropping systems. Agron. Abstr. p. 119.

Presentations to Visitors:

- Nelson Araujo, Producer/Anchor, RedeGlobo News, Brazil
- 25 delegates, Agro-Environmental Protection Institute, Mininstry of Agriculture, China
- Wes Jackson, President, The Land Institute, Kansas
- 20 AAAS representatives
- Dr. Naskriyah Mat, Senior Res. Officer, Malaysian Inst. Nuclear Tech. Res., Bangi, Malaysia
- 4 members and staff, Parliment of South Africa
- 130 visitors to the BARC Field Day
- Ms. Bongiuve Njobe Mbuli, Minister of Agr. and Sci., South Africa
- Dr. Leigh Miller, U. of Tazmania, Australia
- Dr. Roelof P. deVilliers, Asst. Dir., ARC-Roodeplaat Vegetables and Ornamentals Plant Inst., South Africa
- 8 representatives, China Ministry of Agriculture Green Food Development Center
- Dr. Dale Blevins, U. of Missouri
- 3 soil scientists, Swedish Univ. of Agric. Sci.
- Dr. Peter Esbjerg, Chairman, Center for Ecology and Environ., Royal Vet. Agric. Univ., Denmark
- David Swaim, Swaim & Assoc. Agronomic Consulting, Indiana
- 25 tours by the BARC Visitor Center

Contact:
John Teasdale
Weed Science Laboratory
Room 342, Bldg. 001
BARC-W
Beltsville, MD 20705
(301) 504-6537
(301) 504-6491
teasdale@asrr.arsusda.gov

THE FARMING SYSTEMS PROJECT: SUSTAINABLE CASH GRAIN PRODUCTION FOR THE MID-ATLANTIC REGION

Laura Lengnick and Robert Hoover, Soil Microbial Systems Laboratory, Natural Resources Institute

Objective: The Farming Systems Project (FSP) was initiated in 1993 to create a field production research setting in which to study the long-term effects of alternative crop production practices on the biological, environmental, and economic aspects of field crop production in the Mid-Atlantic region.

Approach: A multidisciplinary team of scientists from ARS and the University of Maryland is currently being created to conduct the investigation of soil and crop quality, nutrient and pest management, environmental interactions, farm management and profitability using a systems approach in seven farming systems differing primarily in nutrient and weed management strategies.

The FSP farming systems were designed using a collaborative process of meetings and review sessions involving farmers, extension agents, and agricultural researchers from the Mid-Atlantic region and nationally recognized experts in alternative farming practices. The farming systems represented in the FSP include cash grain rotations (primarily corn, wheat and soybeans) of varying length and intensity, with nutrient inputs from green manures, fresh and composted manure, and synthetic fertilizers. Weed management in most of the systems is accomplished using cultural practices with synthetic control limited to rescue applications. For the next 4 to 8 years, the main experiment will investigate the influence of management practices on soil quality and the profitability of farming systems during the transition from conventional to alternative systems. The experiment is expected to continue for an indefinite length of time following the transition period to allow for research activities in the mature farming systems that develop at the site. See Table 1 for a description of farming system practices.

Accomplishments: Final design of the FSP farming systems was completed and the experimental plots were established during the early part of 1996. Basic agronomic data for use in nutrient budgeting, crop pests and weed management and analyses of system profitability were collected by FSP personnel throughout the growing season. Processing and analysis of soil and plant samples collected during 1996 are currently underway.

Research Activities and Cooperators: Basic agronomic data for use in nutrient budgeting, crop pests and weed management and analyses of system profitability are routinely collected by FSP personnel. Current research areas and collaborators include:

(1)nutrient management, L. Lengnick, SMSL,(2)weed management, J. Teasdale, WSL,(3)soil quality, L. Lengnick, SMSL and R. Weil, U. of MD.,(4)soil microbial diversity, J. Buyer, SMSL and D. Fravel, BPDL,(5)soil mycorrhizae: P. Millner and S. Wright, SMSL.

Research Opportunities and Needs: There are a variety of opportunities for BARC scientists and others interested in conducting field-scale, systems-oriented research within the multidisciplinary framework of the farming systems project. Collaborators interested in investigating any aspect of the farming systems - biological or socio-economic - are encouraged to contact the project director. Currently, the project lacks collaborators in several critical areas: water quality, insect and disease management, soil biology and ecology, natural resource accounting, agro-ecosystem dynamics, socio-economics.

Publications from research on the project:

LENGNICK, L.L., HOOVER, R. L. , and DULANEY, W. P. 1996. The BARC Farming Systems Project: Sustainable Cash Grain Production Systems for the Mid-Atlantic Region. Agron. Abstr. p. 55.

Presentations to Visitors:

"Sustainable Farming Systems for the Production of Field Crops in the Middle Atlantic States," July 1996. Beltsville Sustainable Agriculture and Integrated Pest Management Field Day, BARC.

"The Farming Systems Project: Sustainable Agriculture Systems for the Production of Field Crops in the Middle Atlantic Region". National Program Staff Briefing, USDA-ARS, BARC. October 10.

Mr. Alan Gerard, Agriculture Stewardship Coordinator, Pickering Creek Environmental Center, Chesapeake Audubon Society. July 18.

Ms. Janet Sioma, Ecological Agronomist, NRCS Mid-Atlantic Interdisciplinary Resource Team. August 8.

Australian Cotton Farmers' Association tour. August 23.

Dr. Robert Myers, Director of Sustainable Agriculture Programs, USDA-CSREES. September 13.

Dr. Mike Jawson, National Program Leader, Soil Science/ Microbiology. USDA-ARS. October 11.

Mr. David Swain, Swain and Associates, agronomic consultant and member of the North Central Region Sustainable Agriculture Research and Education Administrative Council. October 28.

Contact: Laura Lengnick
Soil Microbial Systems Laboratory
BARC-W
Beltsville, MD 20705
(301) 504-8327
(301) 504-8370 (fax)
Llengnic@asrr.arsusda.gov

Table 1. 1996 Farming Systems Management Practices

Sys. #	Rot. Yr.	Cash Crops	Nutrient Source	Nutrient Applica.	Cover Crops	Weed Mgt.	Tillage
1	2	C G/B	synth	P, SD P, TD/P		synth	
2	2	C G/B	leg/synth	P, SD P, TD/P	 RVC	cultural	CD plant, 2 RH, 2 C D plant/1 RH, 2 C
3	2	C G/B	leg/man	P, SD P	 RVC	cultural	CD plant, 2 C CD plant/1 RH, 2 C , D harvest
4	2	C G/B	leg/comp	P, SD P, TD	 RVC	cultural	CD plant, 2 C CD plant/1 RH, 2 C , D harvest
5	2	C B	leg/org	P, SD P	R RVC	cultural	D plant, 2 C, D harvest CD plant, 2 RH, 2 C, D harvest
6	3	C B/G (G)	leg/comp	P, SD /P, TD	R RVC	cultural	D plant, 2 C, D harvest CD plant, 2 RH, 2 C, D harvest
7	4	C B/G (G)H H	leg/comp	P /P, TD TD TD	R	cultural	CD plant, 2 C, D harvest CD plant, 2 RH, 2 C, D harvest

Sys. #, Rot. Yr.: farming system number, lenth of rotation.
Cash crops: C - feed corn; G - small grain; B - soybeans; H - mixed hay (fall planted orchard grass and frost-seeded red clover).
Nutrient source: synth - commercial fertilizer; org - certified organic commercial fertilizer; man - broiler manure; comp - mixed waste compost (broiler/yard waste); leg - legume cover crop;
Nutrient applica.: timing of nutrient application. P - at planting; SD - sidedress; TD - topdress; H - at harvest (for following cover crop).
Cover crops: R - rye; CC - crimson clover; RC - red clover; HV - hairy vetch, RVC - rye, hairy vetch, clover mix.
Weed Mgt.: weed management. synth - synthetic materials, cultural - cultural techiques, eg., crop rotation, cover crops, fallow periods, timing of planting, crop spacing, building soil quality, cultivation.
Tillage: CD plant - chisel and disk to kill/incorporate covers and/or fertilizer amendments and prepare seedbed; RH - rotary hoe for weed control; C - cultivate for weed control; D - disk to kill covers and/or fertilizer amendments and prepare seedbed.

REPORT ON URBAN - RURAL RESIDUE UTILIZATION DEMONSTRATION STUDY - 1996

Lawrence J. Sikora, Soil Microbial Systems Laboratory, Natural Resources Institute

A sustainable agricultural practice is to recycle residues back to the soil to reduce outside synthetic inputs such as chemical fertilizers. A pilot field study was initiated in 1994 to test the application of various farm and municipal residues using traditional farm equipment and to determine their effect on important grain crops. The materials applied include cattle manure, dairy manure, poultry manure, municipal refuse compost, refuse compost-cattle manure mixture, biosolids compost, farm compost, yard waste and yard waste compost, and alkaline stabilized biosolids and yard waste. Crops grown were corn (*Zea mays* L.), wheat (*Triticum aestivum* L.) and soybean (*Glycine max* L.). Residue applications were repeated in 1995 and 1996. The residues were applied to the entire plot and when corn was planted an additional nitrogen fertilizer application was made to one half the plot.

All materials were applied with a manure spreader with varying success. In 1994, the additional N application resulted in increased yield over that from the residues alone. In 1995, soybean yields were erratic because of the drought. In 1996, application of residues was made to account for 1994 and 1995 carryover of organic N not mineralized in previous years. Mineralization rates used to calculate the carryover were 10 percent the first year, 5 percent the second year and 2 percent of the remaining organic N for subsequent years. As in 1994, the plots were split with 50 percent of the corn N requirement (120 kg ha^{-1}) supplied with ammonium nitrate fertilizer.

Ideally, plot halves receiving additional 50 % N as ammonium nitrate should yield 50 % more if N is the limiting factor. Only in a few instances with biosolids compost, municipal refuse compost, and poultry manure-flyash compost did fertilizer addition result in greater yields. These data suggest that the mineralization rates assumptions are incorrect, N is not limiting or that other ingredients in compost such as trace nutrients affect corn yields. The 1996 data were confounded by borer damage to corn stalks.

An interesting observation in 1996 was stunting and yellowing of corn in the dairy manure solids treatment. Nitrogen fertilizer addition did not correct the stunting suggesting that it was not an N deficiency. Possible cause is manure organic acids that are deleterious to plants.

Contact: Lawarence J. Sikora
Soil Microbial Systems Laboratory
BARC-W
Beltsville,, MD 20705
(301) 504-9384
(301) 504-8370 (fax)
Lsikora@asrr.arsusda.gov

SUSTAINING SYSTEMS FOR MANAGING MANURE FROM DAIRY CATTLE

B. P. Glenn, A. Lefcourt, J. B. Reeves III, J. Van Kessel,
Nutrient Conservation and Metabolism Laboratory,
Livestock and Poultry Sciences Institute

L. L. McConnell, J. J. Meisinger, R. Thompson, R. J. Wright,
Environmental Chemistry Laboratory
P. D. Millner and L. J. Sikora, Soil Microbial Systems Laboratory
C. S. T. Daughtry and Y. C. Lui, Remote Sensing Laboratory
Natural Resources Institute

Objective: A major challenge of the U. S. dairy industry is to optimize milk production and profits while minimizing the environmental impact of excreted nutrients. Various components of the cow-manure-soil-crop cycle are being investigated to develop management strategies for effective recycling and use of manure nutrients.

Approach/Accomplishments: Animal diet can significantly influence nitrogen excreted in feces and urine. Lactating dairy cows fed a diet of alfalfa/high moisture corn excreted 7.5% less nitrogen in the feces than animals fed an alfalfa/dry corn diet. Experiments to quantify ammonia, methane and odor emissions from barns are being developed. Methods are being evaluated/developed for on-farm determination of available nutrients in manure. Cocomposting of dairy manure with municipal refuse compost reduced volatile loss of nitrogen by 90% compared to composting dairy manure alone. Wind tunnels were constructed and used for field measurement of ammonia volatilization from surface applied dairy manure slurry. Three systems: orchardgrass, alfalfa, and corn with spring rye, were established to determine crop response to dairy manure application. Soil and site properties in a 35 ha field have been characterized to allow precision management of forages using dairy manure. Results will be used by researchers, farmers, extension agents and Natural Resources Conservation Service staff to increase nutrient use-efficiency, reduce nutrient losses to the environment and contribute to the development of decision support systems.

Research Activities and Cooperators: There are 12 scientists involved in this multi-disciplinary, integrated research project. A workshop is being planned to receive input from additional cooperators, including farmers, and commodity and process industries.

Research Opportunities and Needs:

1. Odor from dairy barns and from application of manures to fields is a primary concern of neighbors of urban dairy farms. An important component of our project is the identification of ammonia and odorous compound losses from manures. The effects of different manure handling systems on production of ammonia and other gasses will be studied in a newly constructed unique facility that houses dairy cows. This environmental chamber will allow detailed measurement of amounts and types of gaseous losses from dairy cows. Funding was redirected for development of this high priority facility.

2. The 1997 year will be the second growing season for the whole farm study assessing nitrogen flow through three crops. Mineralization of manures applied to crops to assess available nitrogen is being conducted across several experiments. Flow of nitrogen from the crop to manure and and milk protein production will be linked in experiments with lactating dairy cows.

Publications from Research on the Project:

LEFCOURT, A. M., GLENN, B. P., REEVES, J., VAN KESSEL, J.S., DAUGHTRY, C. LU, Y., MCCONNELL, L., MEISINGER, J., THOMPSON, R., WRIGHT, R., MILLNER, P. AND SIKORA, L. Sustainable systems for managing manure from dairy cows. Southeastern Sustainable Animal Waste Management Workshop Proceedings. pp. 311-312. Univ. Georgia Pub. No. ENG978-001

MEISINGER, J. J. and THOMPSON, R. B. 1996. Improving nutrient cycling in animal agriculture systems. Animal Agriculture and the Environment. pp. 92-110. Northeast Reg. Agr. Eng. Serv., Ithaca, NY.

Presentation to Visitors:

- Congressional staffers, March and June, 1996.
- Sustainable Agriculture Field Day presentation, July 1996.
- ARS/University of Maryland Integrated Field Day presentation, August, 1996.
- Dr. Peter Esbjerg, Chairman, Center for Ecology and Environ., Royal Vet. Agric. Univ., Denmark, September, 1996.
- 20 scientists, Iceland Agricultural Research Institute, November, 1996
- Legislative Assistants to the Chairman of the House Agriculture Committee and the Chairman of the Agricultural Appropriations Committee, November, 1996.

- Dr. Aad Jongebreur, IMAG-DLO, Institute of Agricultural and Environmental Engineering, Wageningen, The Netherlands, November, 1996.
- Discussion with University of Guelph scientists, December, 1996.
- Various scientists groups including attendees of the AAAS meeting, Ukranian scientists, Russian scientists.

Contact: Barbara P. Glenn
Nutrient Conservation and Metabolism Laboratory
Room 124-A, Building 200
BARC-E
Beltsville, MD 10705
(301) 504-9100
(301) 504-8162 (fax)
Bglenn@ggpl.arsusda.gov

THE BARC MEADOW PROGRAM

Robert F. Whitcomb and Loring Benedict
Vegetable Laboratory and Farm Management Operations Branch

Thirty-three meadow units, designed to maximize sustainability, were established in 1993-96 to replace lawn (Table 1). About 10% of BARC's lawn area, which is maintained in approximate 10-day mowing cycles, has been placed in the meadow program. The project was a cooperative effort of FMOD and scientific staff and benefited from a large volunteer effort.

Strategies. Eight strategies, varying greatly in required effort and expense, were used for establishment. These were: (1) *Herbicide/till* (4 meadows). Existing vegetation treated with Roundup, followed by one or two tillages, then seeded mechanically with a mix of grass and wildflowers. (2) *Herbicide only* (5 meadows). Same as above, but with tillages replaced with Verticutter treatment post-seeding. (3) *Scalp* (3 meadows). Existing lawn given very close treatment with flail mower. Seeded mechanically or by hand with commercial seed or locally collected seed of native ecotypes. (4) *Laissez faire* (17 meadows). Existing lawn areas, usually on poor soil, were inventoried and, if determined to have a good prospect of providing satisfactory meadow, were permitted to revert to natural aspect. (5) *Floral enhancement* (25 meadows). Meadows of various types were enhanced to varying extents by seeding and/or plugging with wildflowers. (6) *Living mulch* (2 meadows). Well-rooted plants of wildflowers were planted into existing small patches of a good sod-forming grass (e.g., fescue or zoysia). (7) *Thatch* (1 meadow). Existing area of thatch-forming grass was removed from mowing, then mowed at most once per year. (8) *Compost mulch* (1 meadow, plus 1 control). Existing vegetation was killed with herbicide; 3-4" layer of compost was spread on surface, then seeded with wildflower mix.

Experimental designs. Experimental units were whole meadows; because each unit was designed for sustainability, the emergence of a sustainable meadow was considered to confirm the general hypothesis that sustainability can be achieved by proper design. When possible, meadow units of approximately the same size and soil composition were treated in different ways to provide comparisons of different general meadow approaches. These comparisons were: [1] scalp vs. herbicide only (2 replicates); [2] floral enhancement of dry acid meadows by (A) plugging seedlings into meadows receiving (i) no spot pretreatment, (ii) spot treatments of existing vegetation with Roundup, (iii) a "wormtrack" path of herbicide-treated vegetation throughout the

meadow, or (B) seeding into a "wormtrack" created as in treatment iii above (1 replicate); [3] compost mulch treatment vs. similar meadow treated with herbicide, but receiving no compost (1 replicate). Six meadows on the north grounds of the National Agricultural Library provided replicates of the laissez faire approach.

Floral enhancement. A total of 61 species were supplemented into the meadows. In all, 49 species were seeded and 23 were planted or plugged. Eleven species were both seeded and planted; Seeds were collected from 30 local plant species and were partially cleaned before seeding. In 1993-94, more than 60,000 plugs, grown in BARC greenhouses, were planted into 16 meadows.

Data collected. Soil analyses were performed on all meadows for pH, texture, magnesium, phosphorus, potassium, calcium, nitrate, copper, manganese, zinc, organic matter, composition (sand, silt, clay), and cation exchange capacity. Several soil samples were taken from meadows that displayed topographic heterogeneity. Inventories of plant species were taken; 10-12 visits have been made to all meadows established in 1992-93; fewer visits have been made so far to meadows established later. Meadow aspect was documented photographically at irregular intervals in 1993-95. In 1996, each meadow was documented monthly from May to November. Each year, the meadows were scouted for (1) aspect; (2) positive features such as attractive floral displays, unusual or significant plant species discovered; and (3) threatening weed problems. The scientific scouting reports were relayed to the FMOD manager. Finally, each year, meadows were rated as potentially sustainable or not sustainable.

Results.

Aspect. Attractiveness of meadows was enhanced by integrating them into the overall landscape using location, shape, definition of borders by split-rail fence or mowed strips, and construction of paths. Meadows emphasizing floral beauty have been most attractive to the general public. Savanna units with mature oaks may resemble the "Great Barrens" of pre-Columbian Maryland and are interesting from the point of view of conservation. Many native species grow well on BARC's acid, sandy, infertile soils; on such soils, plant communities of conservation interest can be sustained.

Comparisons of methods. Horticultural meadows were relatively expensive to establish but had much more floral color. The scalp strategy proved to be an excellent compromise between cost and floral quality; also, this method produced more stable meadow

systems during the early years of establishment. Laissez faire meadows cost little or nothing to establish and, when the original lawn had been lightly managed for many years, proved to be diverse in their plant species contents. Floral enhancement by plugging was extremely expensive and uncertain; seedlings, once set out, were susceptible to the vagaries of droughts if no provision could be made for irrigation. Pretreatment of xeric meadows with herbicides before plugging did not improve the establishment rate of plugs; competition among plant species is probably not as strong in such meadows as in mesic or wet systems. The single compost mulch meadow, although attractive the first year, was not sustainable and was overwhelmed by lamb's quarters, mile-a-minute vine, and annual grasses, all of which grew to abnormal heights in the rich nutrients provided by the compost.

Soils. Analyses showed that the soil of many meadows was acid, sandy, and nutritionally poor (Table 1). Some meadows showed substantial internal meadow heterogeneity in soil pH and/or nutrient content. More intensively managed lawn areas showed higher levels of calcium, phosphorus, and potassium, suggesting that the soils had been amended by supplementation of nutrients at some time in the past. The single compost meadow had extremely high nutrient levels. Many meadows with poor soils were patchy, with some patches more depauperate than others. The soil condition most frequently associated with barrenness was gravel content.

Biodiversity. Approximate plant species richness totals have been obtained for the 21 meadow units established in 1992-93. Some 10-12 visits per meadow, from May through October, were necessary to assess the species content of each meadow. Delays in recording plant species could be attributed to (1) inherent delay in apparency of individual species, based on the distinctiveness of morphology of their vegetative characters; (2) necessity for some species to bloom before they could be recorded; (3) the "learning curve" of the observers, as they became familiar with the local meadow flora; (4) delayed appearance of some species as a result of the meadow design; and (5) colonizations of species during the discovery process. At present, about 600 species have been recorded for one or another of the 33 meadow units. Because some identifications are tentative, this number could decrease; however, it is just as likely that it will increase as a result of further species discoveries. The intensive inventory of the meadows renewed interest in the BARC flora, which was reexamined and updated by a team led by retired botanist E. E. Terrell. The BARC floral list now contains more than 800 species. Because the entire research

center has not been inventoried as throughly as the meadows, and because the BARC floral list has been conservatively drawn, it is unlikely that the fraction of BARC plant species occurring in the meadows is as high as it would appear from comparing current estimates of the species richness of each system.

Species richness of individual meadows ranged from 82 to 228 species (Table 1). Factors affecting species richness of meadows included soil factors, available moisture, available light (variable in savannas and glades), cultural treatments, other disturbances, numbers of supplemented plant species, proximity to seed sources of other plant species, proximity to roadways, and (for laissez faire meadows) long-term history, including, perhaps, ancient fire history. Some species of conservation significance appeared in laissez faire savanna units that had not been intensively managed prior to meadow construction.

Eight bird species that migrate to the neotropics and that are of conservation interest bred in the savannas: eastern kingbird, eastern wood pewee, great crested flycatcher, red-eyed vireo, yellow-throated vireo, orchard oriole, Baltimore oriole, and blue grosbeak. Although all of these species also bred in other BARC areas, the meadows extended the amount of habitat suitable for them. Houses for eastern bluebirds were erected in six meadows; four were successful. Other field birds (eastern meadowlark, grasshopper sparrow, American woodcock, and bobolink) utilized the meadows during migration.

Management. Once established, management for sustainability required mowing regimes that maximized desirable meadow aspects, while minimizing negative aspects. Positive aspects of savannas consisted of the savanna structure itself, as long as ground layer vegetation did not have distracting visual elements. Positive aspects of other meadows consisted largely of floral blooms, presented in a semiordered aspect so as not to appear "weedy." Horticultural meadows (strategies 1-3) were generally satisfactory in this regard. The most useful tool for managing meadow aspect was the manipulation of growing season mowings. Late May or early June mowings were used in rare cases to reduce growth of cool-season grasses and to encourage midsummer flowering of such species as Maryland meadow beauty. Late July or early August mowings tended to prolong the flowering of warm-season wildflowers (e.g., butterfly weed, purple coneflower, lance-leaved coreopsis, and black-eyed susan) and to reduce the height of weedy flower species. The latter effect converted some "weed" species such as tall goldenrod and white heath aster into showy assets. Midsummer mowings also were important deterrents to annual weeds such as horseweed and prickly lettuce. Fall

mowings were appropriate for meadows that had an unkempt appearance and that were highly visible. It was also necessary to mow some meadows prior to leaf fall, if they were downwind of a large source of leaves, because standing vegetation of meadows proved to be excellent "leaf catchers." It was preferable to wait until the ground was frozen in midwinter for most annual mowings.

In general, weed control could usually be effectively accomplished by mowing. From the outset, meadows adjacent to woods or hedgerows were separated from them by a single mower-width strip that was mowed two or three times during the growing season. A few weed species, such as ragweed, thistles, and exotic grasses were restrained by spot treatment with herbicide. The biggest threat to long-term (20+ years) sustainability in meadows mowed once or twice anually may be the decumbent vines of Japanese honeysuckle and blackberries, many of whose stems escape mowings.

Sustainability. All but two of the meadows are currently considered to be sustainable. Sustainability of these meadows is especially dependant on properly timed mowing. Horticultural meadows involving herbicide quickly developed a plant species profile that could not be predicted prior to establishment. As we have gained experience with laissez faire meadows (17 replicates), we have been able to successfully predict the outcome of meadow establishments by this method, based on soil analyses and preestablishment plant inventories. None of the 31 meadow units contains apparent elements that would force its abandonment in the foreseeable future.

Contact: Robert F. Whitcomb
Vegetable Laboratory
BARC-W
Beltsville, MD 20705
(301) 504-7380
(301) 504-5555 (fax)

BARC MEADOWS AS LAWN REPLACEMENTS

#	Name	Size	Estab	Type[i]	pH	% Sand	N,P,K	Cultural Trtmnts[ii]	Mowing Time	Sus[iii]	Vs[iv]	S[v]
1	011aUpland	3.5	10/93	Hort	5.7	73	052,119,163	Herb,2Xtill,seed	Dec,Jul	+	11	153
2	011a Wet	1.3	10/93	Hort	5.2	50	016,043,097	Herb,2xTill,seed	Winter	+	10	104
3	NALS (n)	1.3	04/94	Hort	5.2	72	037,133,238	Herb,seed	Dec,Jul	+	11	137
4	NALS (sw)	0.7	10/93	Scalp	5.3	74	036,090,138	Flail,vertct	Dec,Jul	+	11	82
5	NALS (se)	0.8	04/94	Hort	5.4	66	037,145,138	Herb,seed,vertct	Dec,Jul	+	10	86
6a	Poultry Herbicided	0.5	11/93	Hort	5.3	52	020,033,123	Herb,seed,vertct	Oct	+	10	105
6b	Poultry Scalped	3.0	11/93	Scalp	5.6	44	020,040,207	Flail,seed,vertct	Oct	+	10	135
7	Poultry Savanna Seeded	0.7	11/93	Scalp	5.5	36	025,110,230	Flail,seed,vertct	Winter	+	8	108
8	Poultry Savanna Not Seeded	8.0	04/94	LaizFair	5.5	43	017,099,198	None	Win,Jul	+	11	228
9	Beef Barn	7.0	04/94	LaizFair	5.0	64	039,335,378	None	May-Sep	+	10	126
10	Statistics Lab	4.3	04/94	LaizFair	4.8	46	012,059,017	None	Win,Jul	+	11	98
11	Oak Barren North	1.8	10/93	LaizFair	4.6	48	006,031,114	None	Win,Jul	+	11	117
12	Oak Barren Savanna	3.2	10/93	LaizFair	4.4	48	001,121,115	None	Win,Jul	+	10	111
13	Oak Barren Center	2.8	10/93	Scalp	4.7	44	001,041,080	Flail,seed,vertct	Win,Jul	+	10	117
14	NALN Oak Savanna	2.5	04/94	LaizFair	4.7	73	014,101,134	None	Win,Jul	+	11	99
15	NALN Fescue	0.8	04/94	LaizFair/Flor	5.1	66	007,040,110	Plug	Winter	+	11	74
16	NALN General	0.8	04/94	LaizFair/Flor	5.0	72	007,039,130	Herb,seed	Winter	+	11	81
17	NALN Zoysia	0.2	04/94	LivMlch	5.8	66	022,059,178	Lime,plug	Winter	+	11	70
18	NALN Eragrostis Hill	2.4	04/94	LaizFair	5.0	72	010,034,118	None	Winter	+	11	109
19	West Xeric	0.3	04/94	LaizFair/Flor	5.1	71	008,032,092	Plug	Winter	+	10	73
20	North Xeric	0.3	04/94	LaizFair/Flor	5.1	75	017,039,126	Herb,plug	Winter	+	10	80
21	SE Xeric	0.4	04/94	LaizFair/Flor	5.0	72	014,035,110	Herb,plug	Winter	+	10	94
22	Floral	0.8	10/94	Hort	5.8	71	045,040,169	Herb,lime,till,seed	Win,Jul	+	7	83
23	East Bidens	2.2	11/94	Hort	5.7	52	025,405,149	Herb,till,seed	(Winter)	+	7	92
24a	Compost	1.0	05/95	Comp	6.7	62	038,750,450	Herb,comp,seed	As needed	-	5	55
24b	Control	3.1	05/95	Hort	4.7	76	004,120,055	Herb,seed	Winter	-	5	84
25	Native	0.7	06/95	Hort	5.0	69	022,149,153	Herb,seed	Win,Jul	+	5	84
26	Fescue Mulch	0.1	06/95	LivMlch	5.8	21	003,085,306	Plug	Win,Jul	+	6	51
27	Bldg 465	2.0	04/95	LaizFair/Flor	4.7	84	001,030,032	Plug	Win,May	+	8	148
28	Springfield Rd	2.4	04/94	LaizFair/Flor	5.0	64	006,056,047	Plug	Win,Jul	+	7	158
29	Cherry Hill North	5.0	04/96	LaizFair	ND[vi]	ND	ND	None	Winter	+	3	104
30	Cherry Hill South	1.5	04/96	LaizFair	ND	ND	ND	None	Winter	+	2	ND
31	Poultry West	2.5	04/95	LaizFair	ND	ND	ND	None	Winter	+	4	102

[i] Hort—Horticultural; Scalp—close mowing, seeding; LaizFair—removal from 10-day mowing regimen; LaizFair/Flor—florally enhanced abandoned lawn; Comp—compost spread over herbicide-treated vegetation, then seeded; LivMlch—existing lawngrass used as living mulch.
[ii] Herb—treated with Roundup; Flail—close cropping with a flail mower; Seed—seeded; Vertct—soil sliced with verticutter; Plug—seedling plugged into meadow
[iii] +—potentially sustainable
[iv] Number of species-seeking visits
[v] Species number
[vi] ND—not done